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Recovery of Sleep, Performance, and Mood Following 38 Hours of Sleep Deprivation Using Naps as a Countermeasure

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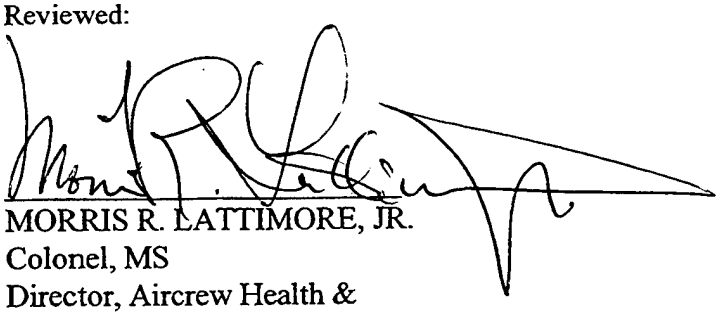

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In certain situations, soldiers must continue to perform their duties over an extended period of time, knowing that their regular sleep period will be missed and their time awake will extend well past 24 hours. Although equipment may be able to operate over extended work hours, personnel are not capable of continuing for days without proper rest and recovery. However, during the times when extended work hours are required, soldiers must find a way to maintain alertness in order to carry out their duties.

When one chooses a countermeasure to aid soldiers' performance, the decision is based on how well the method will increase alertness and performance. However, one must also examine how a person will recover from the countermeasure, how long it will take before he/she is ready to continue the work schedule, and what consequences will occur due to the countermeasure. Many studies are aimed at how well countermeasures work in the short run, but neglect to examine the aftereffects.

The study from which the sleep and recovery data were taken investigated the usefulness

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of zolpidem and prophylactic naps during which subjects were sleep deprived for 38 hours. The first objective was to examine the effects of a 2-hour nap on sustaining performance over a 38-hour continuous work period. This situation was compared to 38 hours of continuous wakefulness with no nap allowed. The second objective was to determine whether a short-acting hypnotic would enhance the quality of sleep during the nap and, therefore, lead to higher alertness during the subsequent work period. Briefly, the results indicated that the naps were beneficial in sustaining mood, alertness, and performance throughout the final 24 hours of continuous work periods. Physiological and subjective measures of alertness indicated that a 2-hour nap was more beneficial than rest in maintaining performance.

The objective of this data analysis was to determine if a soldier recovered from 38 hours of continuous work more quickly when a 2-hour nap was taken during the 38 hours than when only a rest period was given. Also, the impact of using a medication to promote the nap was evaluated in terms of recovery. The quality of sleep was examined during the recovery night as well as next-day performance, mood, and sleepiness levels.

The results indicated that 10 hours of sleep following 38 hours of continuous wakefulness, with the addition of a 2-hour nap, is generally adequate to recover from the effects of sleep deprivation, with the exception of a possible decrement in morning alertness following wake-up from recovery sleep. Although baseline performance generally was not different from recovery performance, alertness and mood were affected up to 2 hours post-awakening. This was probably due to sleep inertia effect from circadian disruption which occurred from the deeper sleep obtained following sleep deprivation. Although alertness was affected, subjects were not pathologically sleepy, taking at least 14 minutes before falling asleep during the Repeated Test of Sustained Wakefulness (RTSW).

It appears that the countermeasure of napping is a viable choice for helping aviators to maintain alertness during an expected continuous operations period. Although the addition of zolpidem to promote sleep during the nap was not overwhelmingly different from a natural nap in its effects on performance, it did produce better performance and alertness than placebo and led to a less intense recovery sleep, which may be important when one might be awakened to return to duty earlier than expected.

In conclusion, it appears that the aftereffects of using napping as a countermeasure during sustained operations are minimal and certainly are better than the effects of total sleep deprivation with no sleep allowed at all. The most significant finding is the prolonged sleep inertia following the recovery sleep period, however, this effect occurred even without the napping intervention.

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Military Relevance

In certain situations, soldiers must continue to perform their duties over an extended period of time, knowing that their regular sleep period will be missed and their time awake will extend well past 24 hours. Although equipment may be able to operate over extended work hours, personnel are not capable of continuing for days without proper rest and recovery. However, during the times when extended work hours are required, soldiers must find a way to maintain alertness in order to carry out their duties.

With the downsizing of U.S. military forces, soldiers are required to continue to achieve the same amount of work as when more soldiers were available to accomplish the mission. The longer work hours have led commanders to search for ways to optimize performance and minimize down-time. Some of the countermeasures which have been suggested have been "go pills" to keep soldiers awake when sleep is not an option, sleeping pills to help soldiers take the most advantage of sleep when sleep is possible, and naps to compensate for times when full sleep periods are not available. Each of these countermeasures is useful in its own place, but the consequences of each one must be examined and taken into account before choosing the appropriate countermeasure for the situation at hand.

When one chooses a countermeasure to aid soldiers' performance, the decision is based on how well the method will increase alertness and performance. However, one must also examine how a person will recover from the countermeasure, how long it will take before he/she is ready to continue the work schedule, and what consequences will occur due to the countermeasure. Many studies are aimed at how well a countermeasure works in the short run, but neglect to examine the aftereffects. For example, dextroamphetamine has been shown to be highly effective at maintaining alertness during sustained operations (Caldwell, Caldwell, and Crowley, 1997; Caldwell and Caldwell, 1997a), however, before using this countermeasure, care must be taken to give the last dose early enough to allow the drug to clear so the person is able to obtain recovery sleep when the opportunity arises. An investigation concerning the recovery sleep following sleep deprivation with the use of dextroamphetamine indicated that sleep was less restorative even after discontinuing the drug 15 hours before bedtime (Caldwell and Caldwell, 1997b).

Using naps to help people maintain alertness during continuous operations is another proven countermeasure for fatigue and sleep deprivation (Bonnet, 1991; Dinges et al., 1988; Haslam, 1985; Lubin et al., 1976; Lumley et al., 1986). Once again, one should determine if the nap will affect recovery sleep once the opportunity for sleep occurs. If the nap is placed too close to the recovery sleep period, it may delay sleep onset and lighten sleep to the extent that a restful recovery is hampered. Also, if a drug is used to promote napping, there could be hangover effects that would degrade next-day performance.

Objectives

The objective of this data analysis was to determine if a soldier recovered from 38 hours of continuous work more quickly when a 2-hour nap was taken during the 38 hours than when only

a rest period was given. Also, the impact of using a medication to promote the nap was evaluated in terms of recovery. The quality of sleep was examined during the recovery night, as well as next-day performance, mood, and sleepiness levels.

Background

When a sleep deprivation period is completed, recovery sleep occurs with a very predictable pattern. The sleep is deeper than normal sleep, with more slow wave sleep occurring during the night, leading to a higher arousal threshold. Usually, rapid eye movement (REM) sleep is unaffected, but it may be delayed during the first night, with a rebound occurring on the second recovery night. Many studies have been conducted in which subjects were kept awake for 36 to 64 hours, after which sleep was recorded and examined. Reynolds et al. (1986) reported an increase in slow wave sleep, a decrease in stages 1 and 2 sleep, and a decrease in REM sleep latency after subjects had been awake for 40 hours. Other researchers have shown similar findings to these, as well as an increase in total sleep time and a decrease in wake time after sleep onset (WASO) (Brendel et al., 1990; Carskadon and Dement, 1985; Daurat et al., 1997; Sefritz et al., 1995). Investigators who have kept subjects awake for periods longer than 40 hours have reported similar results (Rosa, Bonnet, and Warm, 1983; Moses et al., 1975; Akerstedt and Gillberg, 1979; Carskadon and Dement, 1979).

In addition to the recovery of sleep itself, researchers have also examined the recovery of performance, mood, and alertness following a sleep deprivation period. Most researchers agree that performance recovers to baseline levels following up to 40 hours of continuous wakefulness with only 8 hours of recovery sleep (Rosa, Bonnet, and Warm, 1983; Carskadon and Dement, 1979; Haslam, 1982). Most also report that mood recovers after 8 hours of sleep (Carskadon and Dement, 1979; Reynolds et al., 1986), while objective sleepiness may take longer (Carskadon and Dement, 1979). Periods of wakefulness longer than 40 hours also usually show a recovery of performance after 8 hours of recovery sleep (Rosa, Bonnet, and Warm, 1983; Bonnet, 1985), but mood and sleepiness take longer to return to baseline (Bonnet, 1985).

One of the reasons why mood and sleepiness may take longer to recover from sleep deprivation than performance is a phenomenon termed "sleep inertia," a period of initial decline in performance and mood which typically dissipates within 5 to 15 minutes following awakening (Lubin et al., 1976). This effect has been documented in a number of studies (Rosa, Bonnet, and Warm, 1983; Seminara and Shavelson, 1969; Webb and Agnew, 1964). However, in a study by Taub (1979), sleep inertia lasted as long as 2 hours when subjects were awakened from a 2-hour nap which consisted of mainly slow wave sleep. Thus, it appears sleep inertia may be longer and stronger after awakening from recovery sleep following sleep deprivation than it would be upon awakening from a normal night of sleep. Wilkinson (1963) noted that performance following recovery from sleep deprivation is adversely affected early in the morning, but returns to normal as the day progresses, a possible effect of sleep inertia rather than insufficient recovery sleep. Since this affect appears to be strong, recovery from continuous work in which prolonged sleep deprivation occurs should take into account the extra time required to become alert upon awakening.

One thing which may aid in recovery from long bouts of work is the addition of a nap during the sleep deprivation period. There are numerous studies which indicate that a nap taken during an otherwise continuous wakefulness period is beneficial for improving alertness and performance (Akerstedt and Torsvall, 1985; Bonnet, 1990; 1991; Dinges et al., 1987; Dinges et al., 1988; Haslam, 1985; Lumley et al., 1986; Matsumoto and Harada, 1994; Rogers et al., 1989; Naitoh and Angus, 1989; Naitoh, Englund, and Ryman, 1982; Rogers et al., 1989; Rosa, 1993, Webb, 1987). A number of factors determine what effect napping has on subsequent performance and alertness. A nap taken during the day before an all-night work shift will result in improved performance over the night compared to performance without a nap (Schweitzer, Muehlback, and Walsh, 1992; Bonnet, 1991; Naitoh et al., 1982; Dinges et al., 1987). The longer the nap, the better the improvement in performance and alertness (Bonnet, 1991; Lumley et al., 1986). Also, the placement of the nap will determine the quality of sleep, as well as the amount of sleep inertia experienced upon awakening. A nap placed in the circadian trough will lead to longer sleep inertia than naps placed in the circadian peak (Dinges, 1986; Dinges, Orne, and Orne, 1985; Lavie and Weler, 1989). Generally, naps will have positive effects on performance during a period of sleep deprivation, especially if they are taken before significant sleep loss occurs, are as long as possible, and are timed in relation to the work requirements. However, while sleep occurs more readily when a nap is placed in the circadian trough, sleep inertia is worse upon awakening, so an appropriate amount of time should be placed between waking up from the nap and returning to duty.

A nap will also affect recovery sleep following the period of sleep deprivation. If sleep occurs somewhere prior to the regular sleep period, the amount of slow wave sleep during recovery is reduced (Borbely, 1982; Feinberg, Fein, and Floyd, 1980). This reduction in slow wave sleep indicates there is less sleep "pressure" and therefore, less need for the deeper form of sleep. Discussions by Borbely (1982) and Daan, Beersma, and Borbely (1984) indicate that the amount of slow wave sleep is determined by the amount of time since the last sleep period, which would help explain why a daytime nap may reduce amounts of nocturnal slow wave sleep.

As discussed above, the appropriate scheduling of naps is essential for getting the most benefit from a short amount of sleep. Research has shown that naps placed prior to prolonged work periods are beneficial in helping sustain performance. However, naps are not easily obtained in some situations, which leads to the question of whether a sleeping pill may be useful to help promote a short sleep before engaging in a long continuous work period. In some situations, it may not be possible to schedule the nap at the most opportune time. Soldiers may be given adequate time to nap, but the nap may be placed during a "forbidden zone" (Lavie, 1986) in which sleep will not come easily. In these situations, a short-acting hypnotic such as zolpidem tartrate (Ambien®) may be useful. The hypnotic effect of zolpidem has been established through clinical trials with an absence of rebound insomnia, tolerance, withdrawal symptoms, and drug interactions (Bartholini, 1988). Research also indicates that therapeutic doses of zolpidem (5 - 10 mg at bedtime) do not change the sleep architecture of normal sleepers (Blois et al., 1993; Merlotti et al., 1989) and produce few residual effects (Blois et al., 1993). Most studies indicate that next-day performance is not affected by nighttime administration of 5 or 10 mg zolpidem (Quera-Salva et al., 1994; Richens et al., 1993; Sicard et al., 1993). With

these characteristics, zolpidem appears to be the drug of choice for short-term sleep when a pharmacologic therapy is needed.

Caldwell et al. (1997) investigated the usefulness of zolpidem and prophylactic naps in a study during which subjects were sleep deprived for 38 hours. The first objective was to examine the effects of a 2-hour nap on sustaining performance over a 38-hour continuous work period. This situation was compared to 38 hours of continuous wakefulness with no nap allowed. The second objective was to determine whether a short-acting hypnotic would enhance the quality of sleep during the nap and, therefore, lead to higher alertness during the subsequent work period. Briefly, the results indicated that the naps were beneficial in sustaining mood, alertness, and performance throughout the final 24 hours of continuous work periods. Physiological and subjective measures of alertness indicated that a 2-hour nap was more beneficial than rest in maintaining performance. Post-nap sleep inertia was present for about 3 hours following the naps, regardless of whether zolpidem or placebo was administered. The administration of zolpidem before the nap significantly increased the total sleep time obtained during the 2-hour nap period by decreasing sleep onset and increasing deep sleep. However, the advantages of the zolpidem-induced nap in terms of alertness and performance were small compared to the placebo nap.

Since napping, whether drug-induced or natural, can aid in maintaining alertness during a continuous work period, this is a viable countermeasure for commanders when sleep deprivation is inevitable. In addition, if a nap can improve recovery from sleep deprivation, there may be no adverse effects of this countermeasure, thus adding to the desirability of using napping to sustain performance. In the present analysis, recovery sleep, mood, sleepiness, and cognitive performance were examined to determine how well subjects recuperated after 38 hours of continuous wakefulness which included either a 2-hour rest or a 2-hour nap initiated with either 10 mg of zolpidem tartrate or placebo.

Methods

Subjects

Eighteen subjects between the ages of 22 and 31 (mean=24.4) volunteered from Fort Rucker, Alabama, and other Army installations. All subjects were males since no females volunteered to participate. Subjects were either rated pilots (4) or flight students (14). All volunteers gave informed consent following full explanation of the study and were medically evaluated prior to testing. Only healthy, nonsmokers, who used small amounts of caffeine (no more than 3 cups of coffee or 5 soft drinks per day), were included as potential subjects. All were screened for medical problems, including sleep abnormalities, tobacco use, and use of medications that could not be discontinued during the study (except for sodium naproxin, ibuprophen, acetaminophen, or aspirin). Subjects were requested to abstain from drug and alcohol use for at least 48 hours prior to the beginning of the study, and no drug or alcohol use was permitted during the study. Subjects were housed inside the U.S. Army Aeromedical Research Laboratory at Fort Rucker, Alabama, for the duration of testing (10 consecutive days and 9 nights).

Apparatus

Mood evaluation

The Profile of Mood States (POMS) (McNair, Lorr, and Droppleman, 1981) was used to assess subjective mood at various times throughout the testing periods. This paper-and-pencil questionnaire consists of 65 items which measure affect on 6 scales: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. The answers were hand-scored with scoring templates.

Sleepiness evaluations

Visual Analog Scale (VAS). The VAS consists of a 100-mm line centered over each of 8 adjectives: "alert/able to concentrate," "anxious," "energetic," "feel confident," "irritable," "jittery/nervous," "sleepy," "talkative" (Penetar et al., 1993). At the extremes of each line, "not at all" and "extremely" were printed. The subject placed a mark on each line to indicate his current status. The score on each adjective was the distance in millimeters of the subject's mark from the left end of each line to yield a measure a of subjective sleepiness.

Repeated Test of Sustained Wakefulness (RTSW). The RTSW (Hartse, Roth, and Zorick, 1982) is an objective measure of alertness in which the subject's electroencephalogram (EEG) was recorded for up to 20 minutes on a Nihon Kohden electroencephalograph (Model No. EEG-4321P)* to determine how long the subject could stay awake. If sleep occurred, the subject was awakened immediately, removed from the room, and the test ended. If the subject did not sleep, the test was terminated after 20 minutes. Records were scored in terms of the number of minutes from lights out until sleep onset.

Cognitive evaluations

The Multi-Attribute Test Battery (MATB) is a computerized test controlled by a 486 computer equipped with a standard keyboard, a joystick, and a mouse. It requires subjects to perform an unstable tracking task while simultaneously monitoring warning lights and dials, responding to auditory requests to adjust radio frequencies, and managing simulated fuel flow rates. Data on tracking errors, response times, time outs, false alarms, and accuracy rates were calculated automatically by computer.

Additional Tests

Data from performance on a desktop flight simulator and the Synthetic Work Battery also were collected during the study, but due to their insensitivity to sleep deprivation and their prolonged training curves, the results of those tests will not be included in this analysis.

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*See Appendix, Manufacturer's List

Polysomnography

A Nihon Kohden electroencephalograph, Model No. EEG-4321P* was used to collect sleep data during naps and on baseline and recovery sleep nights. The EEG data were recorded from electrode sites C3, C4, O1, and O2, referenced to contralateral mastoids (A1 or A2). Electrooculograms (EOG) were recorded from electrodes attached to the outer canthus of each eye and referenced to A1. Electromyograms (EMG) were recorded from submental electrodes affixed with adhesive collars. The time constant for the EEG channels was 0.3 seconds, and the high filter was 35 Hz. For the EOG, the time constant was 5.0 seconds, and the high filter was 10 Hz. For the EMG, the time constant was 0.003 seconds, and the high filter was 120 Hz. The 60 Hz notch filter was used when necessary. For EEG data collection, Grass E5SH silver cup electrodes* were attached to each subject's scalp with collodion for the duration of the study. EOG and EMG electrodes were attached prior to the nap or nighttime sleep. These were removed each day upon awakening.

Procedure

During three sleep deprivation periods, each subject completed several test sessions consisting of cognitive batteries, flight simulation, sleepiness and electrophysiological evaluations, and mood state questionnaires. Subjects were tested following a 2-hour nap induced with 10 mg zolpidem tartrate (Znap), a 2-hour nap with placebo (Pnap), and a 2-hour rest period with no nap (Nonap). Subjects were permitted 10 hours of sleep after each deprivation condition, termed the recovery sleep. The first day after awakening from each recovery sleep episode was their recovery test day. The conditions were counterbalanced and the drug administration was double-blind. The full experimental protocol and results of the sleep deprivation days are described in Caldwell et al. (1997). Only the procedures relevant to the recovery data analyses will be described here.

Mood evaluation

The POMS was administered every 2 hours beginning at 0900 and ending at 1900 on the training, baseline, and recovery days. The test was administered using the standard POMS answer sheet on which subjects described the way they were feeling at the time. The test took approximately 5 minutes to complete.

Sleepiness evaluations

VAS. The VAS was administered every hour on the hour from 0900 to 2000 on training, baseline, and recovery days. A test sheet containing the eight adjectives described earlier were given to the subject, who placed a mark on a line to indicate his present feelings.

RTSW. The RTSW occurred every 2 hours, beginning at 1010 and ending at 2010, on the training, baseline, and recovery days. The subjects reclined on a bed in a dark, quiet room with the instructions: "lie as still as possible with your eyes closed and do your best to remain awake." During the test, EEG data were recorded from electrode sites C3, C4, O1, and O2,

referenced to contralateral mastoids. The subject was allowed to remain in bed either until 20 minutes had elapsed or until the first indications of stage 2 sleep (the first k complex or sleep spindle) occurred. The elapsed time from lights out until sleep onset was recorded.

Cognitive evaluations

Subjects completed the MATB every 4 hours beginning at 0910 and ending at 1710 on training, baseline, and recovery days. The test was 30 minutes in length. Subjects were required to simultaneously monitor and respond to four different tasks throughout the testing period. The resource management task required subjects to maintain 2500 units of "fuel" in 2 tanks by monitoring and controlling the status of 8 "pumps." The communications task required subjects to monitor verbal instructions about radio-frequency changes presented via headphones and respond only to the ones preceded by their unique call sign (NGT504). The systems monitoring task required subjects to attend to two warning lights and four dials and to press specific keys either to terminate the onset of a specific light or to reset a dial deviating more than two tick marks from center. The tracking task required subjects to center an unstable target in the middle of the top right quadrant of the computer screen. Each task's scores on accuracy and speed were recorded automatically by computer.

Polysomnography

EEG, EOG, and EMG were recorded on the baseline night and the recovery nights following sleep deprivation in order to assess sleep quality. Approximately 15 minutes before lights out, EOG and EMG electrodes were placed. EEG electrodes remained in place throughout the study and were repaired as needed. The subjects then were escorted to private bedrooms where electrodes were plugged into the preamplifiers and signal quality was assessed. Afterwards, the lights were turned out, and the subjects were permitted to sleep. The first night of sleep was the first Sunday, which served as the adaptation night. Monday night served as the baseline sleep night. Wednesday, Friday, and the second Sunday nights were recovery nights. Lights out on all of these nights was 2200, with wake-up time at 0800 the next morning. Subjects were allowed to arise earlier if they requested to do so. Naps occurred from 2100 to 2300 on Tuesday, Thursday, and Saturday nights. All sleep data, including naps, were recorded on standard polygraph paper and were scored according to standard rules (Rechtschaffen and Kales, 1968). Data included sleep latency (number of minutes from lights out to the first full minute of stage 2 sleep), time spent in each sleep stage (minutes and percent), movement time, and WASO.

Testing schedule

Each subject reported to the U.S. Army Aeromedical Research Laboratory (USAARL) on Sunday afternoon. Following the informed consent and medical record review, electrodes were attached. Initial training was then conducted on several of the tests. The adaptation sleep period began at 2200 on Sunday night. Subjects were awakened at 0800 Monday and training sessions occurred at 0900, 1300, and 1700. During each training session, subjects completed all tests in the sequence to be used for the remaining 8 days: POMS, VAS, MATB, RTSW, EEG, Synthetic Work Battery (SYNWORK), and desktop flight simulator. There was an additional RTSW at the

end of each session. Subjects slept from 2200-0800 on Monday night, the baseline night. On Tuesday (a control day), the schedule was the same as Monday except the subject was not allowed to sleep at night. Instead, he received the first of three interventions: 1) a 2-hour nap with 10 mg zolpidem tartrate (Znap), 2) a 2-hour nap with placebo (Pnap), or 3) a 2-hour rest period during which no sleep occurred (Nonap). Each intervention began at 2100 and ended at 2300. For the nap conditions, the drug or placebo was administered 30 minutes prior to lights out. The drug was placed inside a gelatin capsule, while the placebo consisted of a lactose-filled gelatine capsule identical in color and size to the zolpidem capsule. In the Nonap condition, subjects spent their time watching television and conversing with staff members. They were monitored at all times to ensure that no sleep occurred during this period. On Wednesday, testing sessions began at 0100 and continued in sessions beginning every 4 hours until recovery sleep was allowed at 2200 on Wednesday night. Thursday and Saturday schedules were the same as Tuesday; Friday and Sunday schedules were the same as Wednesday. Recovery days occurred on Thursday, Saturday, and the second Monday of the 10-day protocol, immediately following recovery sleep. On the morning of the second Tuesday, subjects were evaluated and released. See Table 1 for a full schedule of each day's test session.

Data Analysis

The data collected from each of the above measures were analyzed with a two-way analysis of variance (ANOVA) with repeated measures for recovery condition (baseline, Znap, Pnap, and Nonap) and time. The alpha level was set at .05, with Huynh-Feldt corrected degrees of freedom used when significant departures from the assumption of compound symmetry were found. Significant interactions were further analyzed with an analysis of simple effects, and main effects were followed up with pairwise contrasts among the means. When many means were to be compared for one variable, Newman-Keuls posthoc comparisons were made.

Only the data from the baseline and recovery days will be discussed in this paper. The data from the sleep deprivation days were analyzed earlier and the results can be found in Caldwell et. al, (1997).

Results

Mood evaluation

The scores from each of the six scales of the POMS were analyzed in a 4 X 6 ANOVA with repeated measures on condition (Baseline, Znap, Pnap, and Nonap) and time (0900, 1100, 1300, 1500, 1700, and 1900). The analysis indicated a condition main effect for the vigor scale ($F(3,51)=2.88$, $p=.0450$). Post hoc comparisons showed that the baseline condition was significantly higher than the recovery nights following the Znap and Nonap conditions. The means for each of the conditions were: Baseline-17.76, Znap-15.56, Pnap-14.71, and Nonap-15.45. A main effect for time was found on the fatigue scale ($F(5,85)=4.27$, $p=.0016$), with

Table 1.
Testing schedule.

Time	Sunday	Monday Training	Tuesday Baseline	Wednesday Test	Thursday Recovery	Friday Test	Saturday Recovery	Sunday Test	Monday Recovery	Tuesday
0100				VAS/POMS		VAS/POMS		VAS/POMS		
0110				MATB		MATB		MATB		
0200				VAS/RTSW		VAS/RTSW		VAS/RTSW		
0235				EEG/EP		EEG/EP		EEG/EP		
0300				VAS/POMS		VAS/POMS		VAS/POMS		
0330				MiniSim		MiniSim		MiniSim		
0400				VAS/RTSW		VAS/RTSW		VAS/RTSW		
0500				VAS/POMS		VAS/POMS		VAS/POMS		
0510				MATB		MATB		MATB		
0600				VAS/RTSW		VAS/RTSW		VAS/RTSW		
0635				EEG/EP		EEG/EP		EEG/EP		
0700				VAS/POMS		VAS/POMS		VAS/POMS		
0730				MiniSim		MiniSim		MiniSim		
0800		Wake up	Wake up	VAS/RTSW	Wake up	VAS/RTSW	Wake up	VAS/RTSW	Wake up	Wake up
0830		Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
0900 0910		VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	Debrief
1000		VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	Release
1035		EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	
1100		VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	
1130		MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	
1200		VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	
1235		Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	
1300		VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	
1310		MATB	MATB	MATB	MATB	MATB	MATB	MATB	MATB	
1400		VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	
1435		EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	
1500	Arrive	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	
1530	Inservice	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	
1600	Medica	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	
1700 1710	Electrode Hook-up	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	VAS/POMS MATB	
1800	Hook-up	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	
1835		EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	EEG/EP	
1900	Dinner	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	VAS/POMS	
1930	Training	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	MiniSim	
2000		VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	VAS/RTSW	
2035		Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	
2100		PT	Drug/nap	PT	Drug/nap	PT	Drug/Nap	PT	PT	
2130	Vitals	PT/Shower	OR Rest	PT/Shower	OR Rest	PT/Shower	OR Rest	PT/Shower	PT/Shower	
2205	Lights out	Lights out		Lights out		Lights out		Lights out	Lights out	
2300			Wake up/VAS		Wake up/VAS		Wake up/VAS			
2400			Shower		Shower		Shower			

fatigue at the 0900 session significantly higher than fatigue at the 1300, 1700, and 1900 sessions; and fatigue at the 1100 session significantly higher than fatigue at sessions 1300, 1500, 1700 and 1900. The means for these times are shown in Table 2. There was no significant interaction between condition and time.

Table 2.
Effect of time on POMS fatigue scores.

	0900	1100	1300	1500	1700	1900
Mean	1.76	1.56	1.11	1.08	0.78	0.93
(se)	(0.32)	(0.27)	(0.27)	(0.27)	(0.23)	(0.21)

Sleepiness evaluations

VAS

The scores from the VAS were analyzed with a 4 X 12 ANOVA with repeated measures on condition (Baseline, Znap, Pnap, and Nonap) and time (0900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, and 2000). The analysis revealed a significant interaction between condition and time for alertness ($F(33,561)=2.50$, $p<.0001$) and energy ($F(33,561)=1.54$, $p=.0303$). Simple effects analysis indicated differences among the conditions at 0900 for alertness. Post hoc comparisons indicated alertness was higher at 0900 during recovery following Znap than during recovery following Pnap or Nonap, with no difference between baseline and the other conditions (means: Baseline=80; Znap=87; Pnap=77; Nonap= 79). There was a difference among the conditions at 2000 for energy. Post-hoc comparisons found energy was lower at baseline (76) than during the recovery following the Pnap and Nonap conditions (85 and 81, respectively), and energy was lower during the recovery following the Znap condition than following the Pnap condition (75 and 85, respectively). Significant differences were also found among the times for both alertness and energy during the Nonap condition and energy during the Pnap condition. Newman-Keuls post-hoc comparisons showed a lower score for alertness during the Nonap condition at the 1000 session compared to scores at all of the sessions from 1300 until 2000. Energy was higher during the Nonap condition at 1600 than at 1000 and higher during the Pnap condition at 2000 than at 0900, 1100, 1300, and 1600. These results are portrayed in Figure 1.

A main effect for time occurred for alertness ($F(11,187)=2.58$, $p=.0045$), energy ($F(11,187)=2.12$, $p=.0207$), confidence ($F(11,187)=1.93$, $p=.0376$), and talkativeness ($F(11,187)=3.84$, $p=.0001$). Analysis of the means indicated the alertness score was lower at 1000 than at all times from 1100 to 2000, and scores at 1100 were lower than those at 1500.

The scores from the energy scale were lower at 0900 than at 1300 and 1700; lower at 1000 than at 1300, 1400, 1600, 1700, and 2000; and lower at 1100 than at 1300. The scores on the confidence scale were lower at 1000 than at 1100, 1500, 1600, 1900, and 2000; lower at 1200 than at 1600 and 2000; and lower at 1900 than at 2000. The talkativeness score was lower at 0900 than at all sessions from 1200 through 2000, with the exception of 1900; the score at 1000 was lower than scores from 1200 to 2000, with the exception of 1900; and the score at 1100 was lower than the scores at 1400, 1500, 1700, and 1900. The scores from the session at 1900 were higher than those at 1400, 1700, and 1800. The means are shown in Table 3. There was no significant main effect for condition on any of these scales.

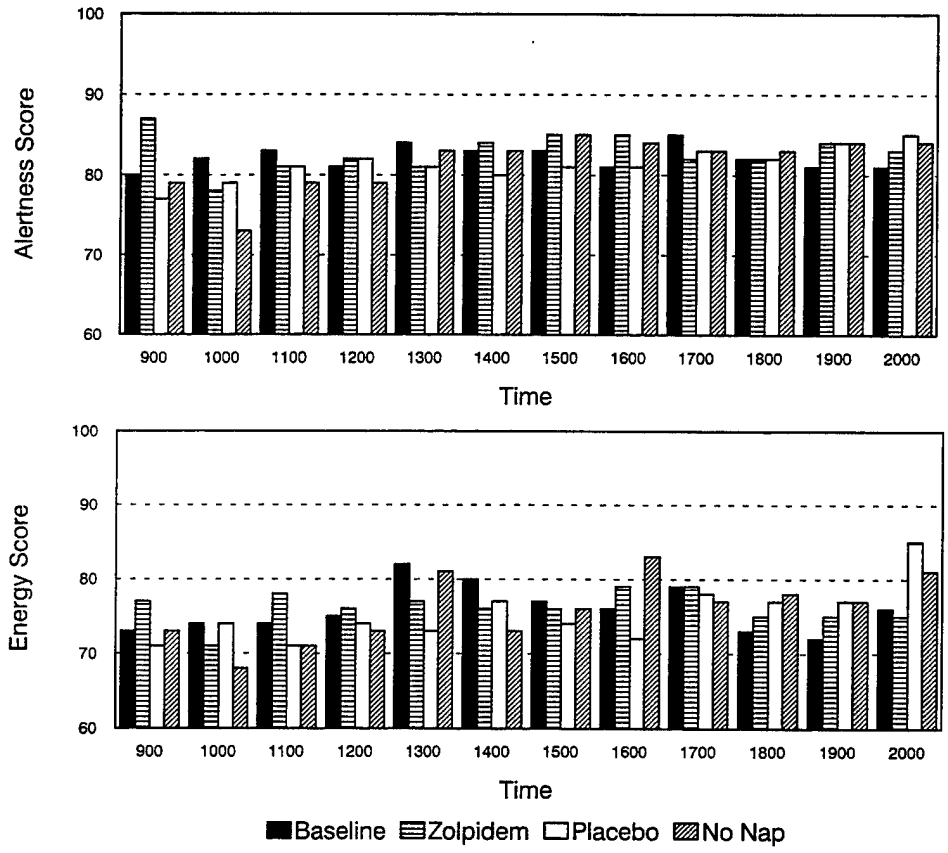

Figure 1. Alertness and energy scores by condition and time.

RTSW

The data from the RTSW were analyzed with a 4 X 6 ANOVA with repeated measures on condition (Baseline, Znap, Pnap, and Nonap) and time (1010, 12010, 1410, 1610, 1810, and 2010). A significant interaction occurred between condition and time ($F(15,255)=2.03$, $p=.023$) which was due to a difference among the conditions at the 1010 session. Comparisons

among the means indicated that the overall sleep latency during the baseline condition was significantly longer than during the Znap, Pnap, or Nonap conditions (see Figure 2). There was also a difference among the times at all conditions. Paired comparisons indicated that during baseline, the sleep latency at the 1010 session was longer than those at the 1410 and 1810 sessions, and the sleep latency at the 2010 session was longer than those at the 1410, 1610, and 1810 sessions. During the Znap condition, the sleep latency at the 1010 condition was shorter than those at the 1810 and 2010 sessions, and the sleep latency at the 2010 session was longer than those at the 1210 and 1610 sessions. During the Pnap condition, the sleep latency at the 1010 sessions was shorter than those at the 1210, 1610, 1810, and 2010 sessions, and the sleep latency at the 2010 session was longer than those at the 1210, 1410, and 1810 sessions. During the Nonap condition, the sleep latency at the 1010 session was shorter than those at all other sessions, and the sleep latency at the 2010 sessions was longer than those at the 1210, 1410, and 1610 sessions. These results are shown in Figure 2.

Table 3.
Effect of session on factors from the VAS.

	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Alertness	80.89	78.08	81.28	81.16	82.34	82.31	83.50	82.83	82.96	82.44	83.33	83.18
Mean (se)	(1.69)	(1.87)	(1.62)	(1.64)	(1.57)	(1.53)	(1.50)	(1.67)	(1.80)	(1.61)	(1.67)	(1.79)
Energy	73.24	71.64	73.49	74.27	78.29	76.42	75.60	77.33	78.36	75.74	75.13	79.00
	(2.47)	(2.50)	(2.53)	(2.50)	(2.31)	(2.45)	(2.82)	(2.60)	(2.33)	(2.48)	(2.71)	(2.02)
Confidence	83.17	81.60	84.21	82.31	83.92	84.56	85.14	86.03	84.49	85.40	84.24	86.32
	(1.96)	(1.79)	(1.96)	(1.90)	(1.85)	(1.63)	(1.68)	(1.65)	(1.76)	(1.63)	(1.84)	(1.63)
Talkativeness	56.79	57.61	60.03	62.48	63.32	63.58	83.50	82.83	82.96	82.44	83.33	83.18
	(2.92)	(2.69)	(2.85)	(2.89)	(2.78)	(2.88)	(1.50)	(1.67)	(1.80)	(1.61)	(1.67)	(1.79)

A significant main effect for time ($F(5,85)=7.86$, $p<.0001$) was due to an overall shorter sleep latency at the 1010 session than at the 1210, 1610, 1810, and 2010 sessions, and shorter sleep latencies at the 1210, 1410, 1610, and 1810 sessions than at the 2010 session. These data are shown in Table 4. No significant effect occurred on the condition factor.

Cognitive evaluations

Scores on the four subtests of the MATB were analyzed separately with a 4 X 3 ANOVA with repeated measures on condition (Baseline, Znap, Pnap, and Nonap) and time (0910, 1310, and 1710). Significant findings were revealed on scores from the communications task and the systems monitoring task. No significant findings occurred for the resource management and tracking subtests.

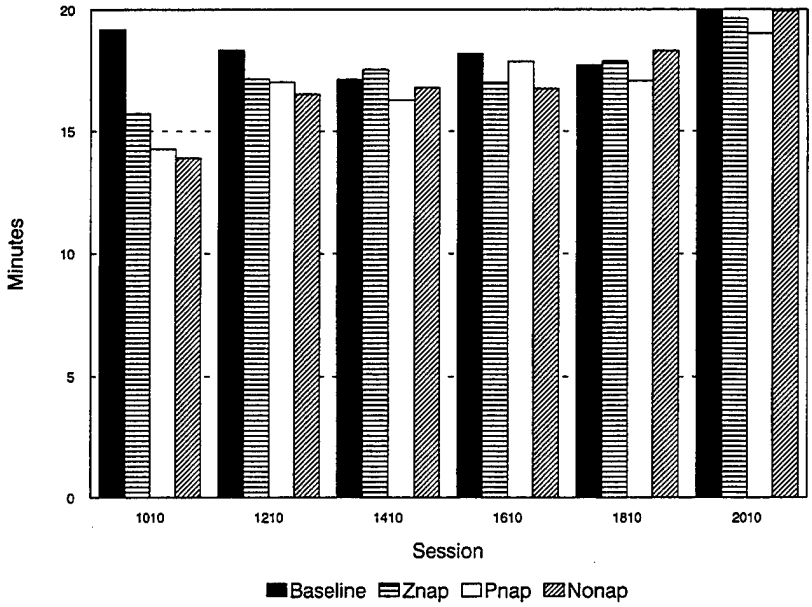

Figure 2. Sleep onset for RTSW by condition.

Table 4.
Effect of session on sleep latencies from the RTSW.

Session	1010	1210	1410	1610	1810	2010
Mean	15.77	17.25	16.93	17.46	17.75	19.65
(se)	90.62)	(0.50)	(0.53)	(0.47)	90.47)	(0.19)

Communications

Scores from this subtest consisted of the mean reaction time (RT) for correct responses, the standard deviations of reaction times (SDRT) for correct responses, and the number of time-out errors. A significant interaction occurred between condition and time for the time-out errors ($F(6,102)=2.67$, $p=.0380$). Analysis of simple effects indicated differences among the conditions at each time. There were fewer errors at baseline than the other conditions at all the sessions. In addition, at the 1310 session, the errors during the Znap condition were lower than the errors during the Pnap or Nonap conditions. At the 1710 session, the errors during the Pnap were higher than the errors during the Nonap condition. Simple effects analysis also revealed differences among the times during the Pnap condition, but not during the other

conditions. Mean comparisons during the Pnap condition indicated that the errors during the 0910 sessions were significantly lower than at the 1310 session. These effects are shown in Figure 3.

A main effect for condition occurred for the SDRT for correct responses ($F(3,51)=6.51$, $p=.0012$) and for the number of time-out errors ($F(3,51)=7.06$, $p=.0061$). Comparisons among the means indicated that the SDRT for correct responses were lower and the time-out errors were fewer during the baseline condition than during the other conditions. (See Table 5.)

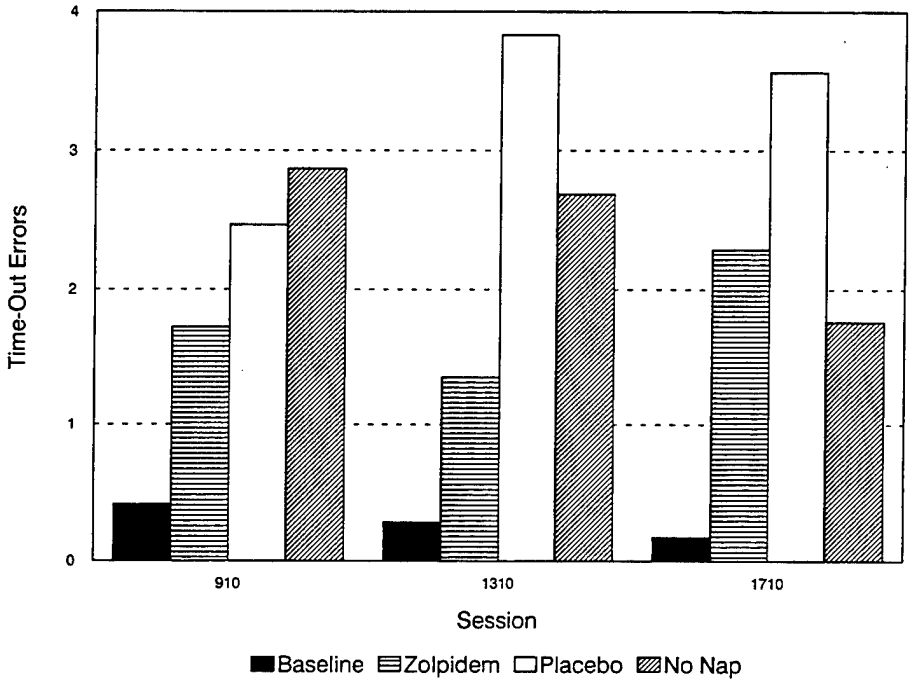

Figure 3. Session effects for each condition on the communication subtask of the MATB.

Systems monitoring

Scores from this subtest consisted of the RT for responding to lights, the RT for responding to dial deviations, the SDRT for lights, the SDRT for dials, time-out errors for lights, and time-out errors for dials. The ANOVA revealed a main effect for condition for the RT for dials ($F(3,51)=11.09$, $p<.0001$). Post-hoc comparisons indicated longer RT to dials during the baseline condition than during the Znap, Pnap, or Nonap conditions, with mean RTs of 5.17, 4.23, 4.46, and 4.23, respectively. A main effect for time also occurred for RT to dials ($F(2,34)=3.45$, $p=.0434$). Post-hoc comparisons indicated longer RT to dials during the 0910 session than during the 1310 and 1710 sessions (means were 4.69, 4.45, and 4.42, respectively).

Table 5.

Effect of condition on SDRT and time-out errors on communications subtask of the MATB.

	Baseline	Znap	Pnap	Nonap
SDRT Mean (se)	1.52 (0.07)	1.83 (0.09)	2.17 (0.20)	1.84 (0.11)
Time-out Errors	0.29 (0.09)	1.79 (0.27)	3.29 (0.64)	2.44 (0.42)

Polysomnography

The data from the baseline and recovery nights were analyzed with a one-way repeated measures ANOVA. The variables of interest were minutes in bed, sleep onset (defined as the first full minute of stage 2 sleep), time in minutes and percent time spent in stages 1, 2, 3, 4, and REM sleep, and WASO. Since the minutes and percent data indicated the same results, only the minutes will be discussed here.

The analysis revealed significant condition effects for minutes in bed ($F(3,51)=4.11$, $p=.0110$), sleep onset ($F(3,51)=18.21$, $p<.0001$), minutes in stage 1 ($F(3,51)=24.87$, $p<.0001$), minutes in stage 4 ($F(3,51)=29.95$, $p<.0001$), minutes in stage REM ($F(3,51)=15.21$, $p<.0001$), and WASO ($F(3,51)=14.42$, $p<.0001$). Comparisons among the means indicated that during the baseline night, participants spent shorter amount of time in bed, had a longer sleep onset time, spent more minutes in stage 1 sleep and fewer minutes in stage 4 and REM sleep, and their WASO was longer than during any of the recovery nights. During the recovery night following the zolpidem nap condition, participants had a longer sleep onset than during the recovery night following the Nonap condition. In addition, there was more stage 1 sleep and less stage 4 sleep during the recovery nights following the Znap and the Pnap than during the recovery night following the Nonap condition. Participants also had more WASO during the recovery night following the Znap condition than during the recovery night following the Pnap condition. The minutes of time spent in each stage are shown in Table 6.

Table 6.
Sleep stages per condition.

	Baseline	Znap	Pnap	Nonap
Time in Bed Mean (se)	588.06 (1.55)	591.78 (1.35)	591.78 (1.14)	591.67 (1.28)
Sleep Onset	23.94 (2.75)	11.89 (1.43)	9.14 (1.23)	8.14 (1.45)
Stage 1	50.33 (4.60)	28.47 (2.87)	28.17 (2.70)	23.19 (1.91)
Stage 2	277.64 (8.50)	275.94 (9.21)	274.78 (6.17)	271.31 (7.63)
Stage 3	32.72 (3.07)	40.25 (3.39)	41.22 (3.88)	40.81 (3.47)
Stage 4	41.72 (6.52)	64.67 (7.56)	65.61 (6.24)	81.31 (7.59)
Stage REM	130.56 (5.80)	158.64 (7.09)	166.19 (5.11)	157.89 (5.10)
WASO	26.22 (9.45)	3.64 (0.90)	1.61 (0.40)	3.92 (1.76)

In order to assess more completely the effects of napping on recovery sleep, the polysomnographic data from the recovery nights were analyzed further by examining the minutes spent in each stage during the first hour of sleep and the cumulative amount of time spent in each stage every hour until wake up time. The result of interest from this analysis was the interaction between condition and hour to determine more closely how the subject recovered from sleep deprivation. The interaction between condition and hour was significant for minutes in stage 1 sleep ($F(27,459)=19.86$, $p<.0001$), minutes in stage 4 sleep ($F(27,459)=4.16$, $p<.0001$), minutes in REM sleep ($F(27,459)=5.73$, $p<.0001$), and WASO ($F(27,459)=4.64$, $p=.0384$. Analysis of simple effects revealed a significant effect among the conditions at hour 1 for minutes in stage 1 sleep, cumulative hours 1 through 10 for minutes in stage 4 sleep, cumulative hour 3 and hours 5 through 10 for minutes in REM sleep, and cumulative hours 3 through 10 for WASO. The baseline condition had more stage 1 sleep than the recovery night following the Pnap and Nonap conditions at hour 1, but no difference among the conditions during the remainder of the night. There was less stage 4 sleep during the baseline than during any of the recovery sleep nights beginning at hour 1 and continuing through hour 10. There was also less stage 4 sleep during the recovery night following the Znap condition than the recovery night following the Nonap condition beginning at hour 1 and

continuing through hour 10. The separation in the amount of stage 4 sleep between the recovery night following the Pnap condition and the recovery night following the Nonap condition occurred at hour 3 and continued through hour 10, with less stage 4 during the Pnap condition than during the Nonap condition. In addition to stage 1 sleep and stage 4 sleep, there were fewer minutes in REM sleep during baseline compared to all recovery conditions beginning at cumulative hour 3 and continuing through hour 10. At cumulative hour 6, there was more REM sleep during the recovery following the Pnap condition than following the Nonap condition, but no further differences among the conditions occurred. These relationships are shown in Figure 4.

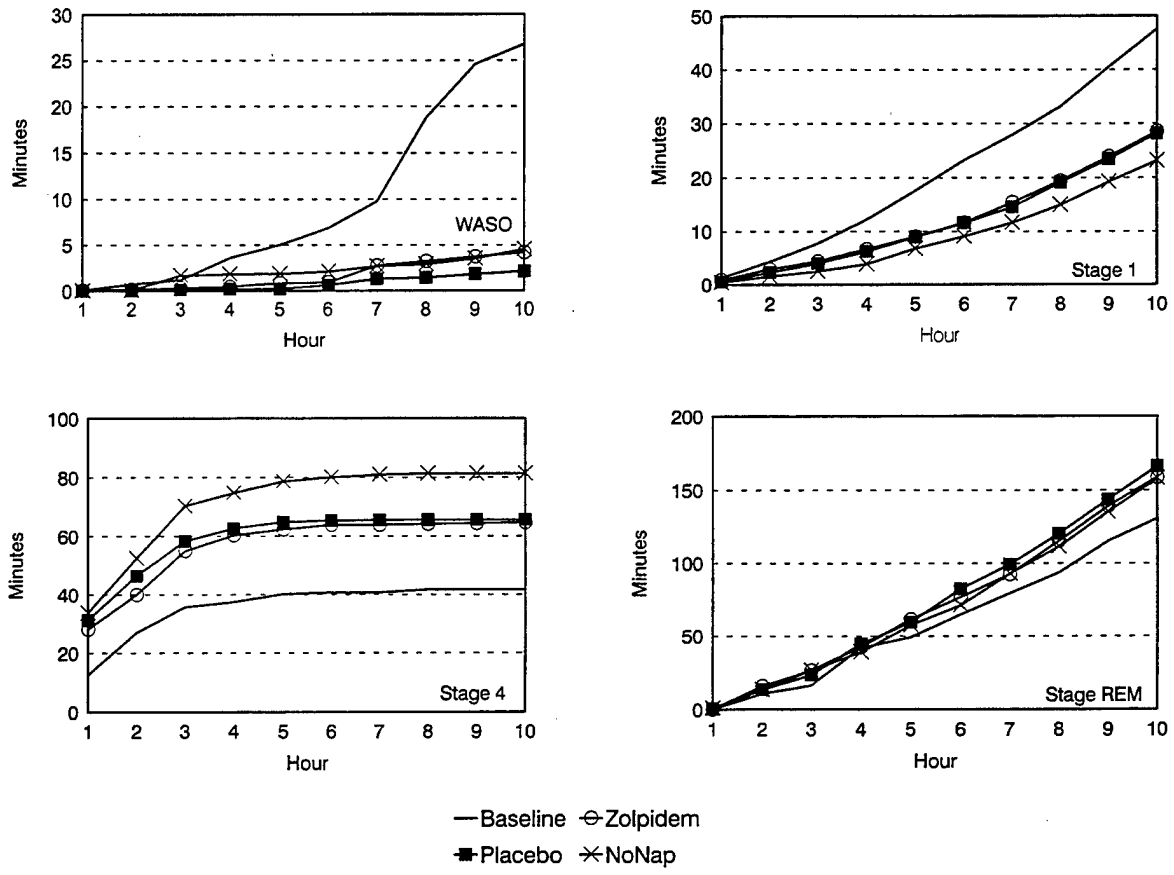

Figure 4. Cumulative minutes in WASO and stages 1, 4, and REM for each condition.

Discussion

The present analysis evaluated the ability of aviators to recover mood, performance, and alertness with one 10-hour recovery night following 38 hours of continuous wakefulness in which there was either a 2-hour nap, aided by 10 mg of zolpidem tartrate or placebo, or a 2-hour rest period. The results of the effects of the naps on performance are discussed elsewhere

(Caldwell et al., 1997; Caldwell and Caldwell, 1998). For this analysis, the results indicated that aviators for the most part were able to recover performance, alertness, and mood after a 10-hour period of recovery sleep, supporting studies by other researchers which indicate that one night of sleep is sufficient to recover from 38 hours of sleep deprivation (Rosa, Bonnet, and Warm, 1983; Carskadon and Dement, 1979; Reynolds et al., 1986). However, sleep inertia effects were seen in mood and alertness for up to 2 hours after awakening from recovery sleep, in comparison to baseline. This effect occurred regardless of whether subjects had a zolpidem-induced nap, a natural nap, or only a rest period during the previous sleep deprivation episode.

Mood evaluation

Five of the six scales from the POMS did not show a difference in subjective mood between baseline and recovery days. However, subjects indicated a higher subjective rating for vigor during the baseline period than during any of the recovery days. This effect could be attributed to overall fatigue from participating in a 10-day study. No interaction between condition and time occurred for mood, which indicates that recovery sleep does not affect subjective mood, regardless of whether a nap during a sleep deprivation period is taken or not.

Sleepiness evaluations

Subjective sleepiness evaluated by the VAS indicated that energy and alertness levels were lowest at 1010 following the recovery from the Nonap condition but not during any of the other conditions. Energy was highest at 2010 during the recovery day after both the Nonap and the Pnap conditons. This rating occurred 2 hours before bedtime, which may have been an end-of-day effect. Although none of the recovery conditions differed from baseline, subjective alertness was higher following recovery after the Znap condition than after the Pnap or Nonap conditions, with no difference from baseline. This effect may have been due to the increased amount of sleep obtained during the Znap, leading to a lighter recovery sleep and less sleep inertia compared to the other two conditions. However, subjective measures of sleepiness did not agree with objective measures of alertness. The RTSW indicated a shorter sleep onset during the 1010 session at all recovery sleep conditions than during the baseline day, indicating decreased physiological alertness following recovery from sleep deprivation, regardless of nap condition. Disagreement between subjective and objective sleepiness has been found in previous studies (Johnson et al., 1991; Chervin, Kraemer, and Guilleminault, 1995; Seidel et al., 1987), but the relationship between objective alertness and subjective sleepiness has not been extensively evaluated. One study has shown that objective alertness is poorly correlated with subjective sleepiness (Caldwell and Ruyak, 1997).

The decreased alertness during the 1010 RTSW could be due either to inadequate recovery from sleep deprivation, sleep inertia, or disruption of normal physiological rhythms. The latter two of these explanations appear more reasonable since the alertness measures for the remainder of the day increased rather than decreased. Other studies have indicated that when a person has been sleep deprived, their sleep is deeper than usual, leading to more sleep inertia upon awakening (Naitoh et al., 1982; Wilkinson, 1963). Inadequate recovery from sleep deprivation is reflected in declining performance, mood, and alertness throughout the day,

whereas, sleep inertia is reflected by poor performance, mood, and alertness initially in the morning, which then dissipates as time progresses. This effect is also explained by the possiblity that sleep deprivation itself disrupts normal circadian rhythms which become re-established by the afternoon following recovery sleep (Wilkinson, 1963). No discrimination among the napping or rest conditions was evident in the RTSW, so it appears that the nap, regardless of whether aided by zolpidem or placebo, did not alleviate the slow wake up from the recovery sleep.

Cognitive evaluation

The MATB assessed skills by requiring the aviators to time-share cognitive resources among several tasks simultaneously as would be required when piloting an aircraft. The results from the performance on one subtest (communications) out of four showed significantly better performance during baseline than during the recovery days, regardless of whether naps or rest was obtained. This effect on performance appears to reflect inadequate recovery from sleep deprivation, however, since only one of the measures on one of the subtests was significantly different from baseline, this effect may have been a spurious effect and not a true reflection of inadequate recovery. No other changes in performance were noted. Also, while fewer time-out errors occurred on the communication subtask during baseline, there were longer reaction times to dials during baseline than during the recovery days which contradicts the idea that inadequate recovery sleep occurred.

Polysomnography

The data from this study indicated better sleep on recovery nights than during the baseline night, as would be expected since the subjects had been awake a minimum of 24 hours before their 10-hour recovery sleep period. The recovery nights, regardless of napping or rest condition, showed deeper sleep when compared to baseline. In addition, there were significant differences in sleep architecture among the conditions which indicated that the naps versus rest only changed the way in which recovery sleep occurred. The recovery sleep was less deep following both the Znap and Pnap conditions than following the Nonap condition. The data from the hour-by-hour examination of sleep architecture indicated that beginning at hour 1, subjects slept more deeply when compared to baseline. However, subjects began to recover from sleep deprivation sooner following the Znap condition than the other conditions. This recovery is reflected in the amount of stage 4 sleep seen early in the sleep period, with more stage 4 sleep early in the night compared to baseline, and a reduction beginning earlier in the night following naps than following rest. The Pnap condition lagged behind the Znap condition in recovery by about an hour. This effect probably occurred because subjects were able to sleep on average about 36 minutes longer during the zolpidem-induced nap than during the placebo nap in the deprivation period. Since deep sleep is dependent upon the amount of time awake since the last sleep period, it is expected that less stage 4 sleep would be seen after continuous wakefulness which includes a nap somewhere in the deprivation period. Although the difference in the amount of sleep obtained between the Znap and Pnap conditions was not enough to affect performance the next day, it was enough to change the sleep architecture during the recovery night.

Summary and conclusions

In summary, it appears that 10 hours of sleep following 38 hours of continuous wakefulness in which a 2-hour nap was included, is generally adequate to recover from the effects of sleep deprivation, with the exception of a possible decrement in morning alertness following wake-up from recovery sleep. Although baseline performance generally was not different from recovery performance, alertness and mood were affected up to 2 hours post-awakening from recovery sleep. This was probably due to sleep inertia effects or from circadian disruption which occurred from the deeper sleep obtained following sleep deprivation. Although alertness was affected, subjects were not pathologically sleepy, taking at least 14 minutes before falling asleep during the RTSW.

It appears that the countermeasure of napping is a viable choice for helping aviators to maintain alertness during an expected continuous operations period. Although the addition of zolpidem to promote sleep during the nap was not overwhelmingly different from a natural nap in its effects on performance (discussed in an earlier report), it did produce better performance and alertness than placebo, and led to a less intense recovery sleep which may be important when one might be awakened to return to duty earlier than expected. The lighter sleep obtained following the zolpidem nap condition indicated less pressure to sleep and, therefore, a better ability to awaken if needed.

In conclusion, it appears that the aftereffects of using napping as a countermeasure during sustained operations are minimal and certainly are better than the aftereffects of total sleep deprivation. The most significant finding is the prolonged sleep inertia following the recovery sleep period, however, this effect occurred even without the napping intervention. Supervisors should take this effect into account when assigning duties following a sleep deprivation period. Although performance recovers well, if workers are assigned boring, monotonous tasks too soon after awakening from their recovery sleep, they may be less alert than usual due to sleep inertia. However, when comparing the results of the present analysis to our previous findings regarding the benefits of naps in sustaining performance, it appears that the benefits obtained by scheduling a nap before an expected continuous work period far outweigh any negative consequences seen during the recovery period.

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Appendix.

Manufacturer's list.

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